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EFFECT OF INERTIA WEIGHT FUNCTIONS OF PSO IN OPTIMIZATION OF WATER DISTRIBUTION NETWORK

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ABSTRACT

Water distribution in adequate quantity at required pressure is the prime requirement of design of network. It is found from the literature, that stochastic methods gives better results in optimizing the water distribution network (WDN) than deterministic methods. The optimize solution obtained from any stochastic method depends on the parameter values associated with that method. In the present work a program is developed in MATLAB environment to optimize the water distribution system using Particle Swarm Optimization (PSO) technique. The analysis is carried out using finite element method. The validity of developed program is demonstrated by comparing results with a benchmark water distribution network. Different values of inertia weight function in Partial swarm optimization has been used to study the effect of this variant on the cost of water distribution network.

Key words: Optimization; Water Distribution Network; Particle Swarm Optimization; Inertia Weight Function

1. INTRODUCTION

A safe supply of potable water is the basic necessity of mankind in the industrialized society, therefore water supply systems are the most important public utility. A huge amount of money is spent every year around the world for providing or upgrading drinking water facilities. The major share of capital investment in a water supply system goes to the water conveyance and water distribution network. [Wu et al,2001]. Therefore it is very important to optimized the network. The methods used for optimization of water distribution network may be deterministic or stochastic [Keedwell et al,20041].Optimization of the network aims to find out the best diameter size from the available commercial diameter sizes to get the minimum cost of the network within head and velocity constraints. Conventional methods gives global optimal solution but they are tedious and time consuming while the stochastic method are more efficient methods[[Afasher et al, 2003]].

It can be seen from the previous work that stochastic methods work successfully for water distribution network. Various optimization techniques e.g. Genetic Algorithm, Ant Colony optimization, artificial neural network etc have been successfully used to optimize the water distribution network but they have their own limitations of rate of convergence, difference between the shortest and the longest optimization response time etc [Izquierdoa, 2014]. Optimization of pipe network by using GA also has limitations like poor convergence, unrealistic global optimum solution etc. To overcome theses limitation, James Kennedy and Russell Eberhart [1995] developed the concept of Particle Swarm Optimization (PSO) to overcome the limitations of GA.

Particle swarm optimization is a robust stochastic technique for optimization [Mahor et al, 2009]. In this method, the co-ordinates of each particle represent the possible solution and after each iteration, the particle moves towards optimal solution. Particle swarm optimization is comparatively topical, very simple and has very fast rate of convergence for various optimization problems. Literature reveals that PSO is successfully worked for optimization of water distribution network. It is seen that optimization of pipe network using PSO has been done taking a particular inertia weight function and effect of other weight function on the optimized results are not studied.

In present work coding is done for optimizing water distribution network using PSO. The network analysis is carried out by finite element method using Darcy Weishback head loss equation the results are validated for two loop water distribution network. The results obtained are having good agreement with the results obtained for the same network by using other stochastic methods of optimization.

The inertia weighted function ‘w’ is one of the important parameter in particle swarm optimization [Bansal et al, 2009, 2011]. In the present paper the cost optimization using eight different variants of inertia weight function are compared and presented in graphical and tabulated form.

2. PROBLEM FORMULATION

Objective function: It is to minimize the cost of water distribution network by selecting commercially available pipe diameter and the objective function is given as;

$$MinZ = \sum_{i=1}^{m} C(L,D)$$

Where Z = total cost ,m = no of pipe in the network C= cost of the pipe having length L and diameter D. The constraints to be satisfied for minimizing the cost of network are;

Constraint 1: **Diameter constraint**

The diameter of the pipe should be selected from the available commercial pipe diameters. Commercially available pipe size and cost of unit length is given in table 1.

Constraint 2: Head constraint

The head available at each junction must be greater than the minimum required head to supply sufficient amount of water at the junction.i.e.

$$H_k \geq H_{\min}$$

where k=1,2,3………………..n

Apart from these two constraints, the network is analysed to meet the following requirement.

1. The continuity equation i.e the amount of water entering to the junction must be equal to the amount of water leaving from the junction.

$$\sum_{j=1}^{j=n} Q = 0 \qquad \text{……… (a)}$$

Where n=no of pipe meeting at any junction

2. Net head loss within the loop must be zero.

$$\sum_{p=1}^{p=nop} H_{LP} = 0 \qquad \text{……….. (b)}$$

Where nop= no of pipes in any loop

Particle Swarm Optimization

Partical swarm optimization is bio inspired met heuristic technique for optimization. James Kennedy and Russell Eberhart developed the concept of PSO in 1995 [Shrivastava et al, 2014]. In this method the co-ordinates of each particle represents the possible solution. After each iteration the objective function is evaluated to help particle to move towards optimal solution

In this method the initial population is generated randomly and based on the objective function it is updated for the best optimal solution. If the initial position of the particle is $x_i(t)$,then after the next iteration it will move to the next position of $x_i(t+1)$. The particle moves toward the best optimal solution using velocity update from $v_i(t)$ to $v_i(t+1)$ as in equation 1 and equation 2.[Izquierdoa et al, 2014].

$$v_i(t+1) = w*v_i(t) + C1*R1*(pbest - x_i(t)) + C2*R2*(gbest - x_i(t)) \qquad \text{-------I}$$
$$x_i(t+1) = x_i(t) + v_i(t+1) \qquad \text{-------II}$$

Where C1 and C2 are the positive constants named as cognitive learning rate and social learning rate respectively, they are used to accelerate the particle towards the optimal solution. R1 and R2 are the uniform random number ranging from 0 to 1. 'pbest' is the best solution obtained by the individual particle and gbest is the best value of objective function from the entire swarm. ‘w’ is the inertia weight function.

3. METHODOLOGY

The MAT LAB environment is used for developing program for optimizing water distribution. The program is developed in two parts. The first part calculates the head and flow in the network for the given set of diameters by using Finite Element methods whereas the optimization is done in the second part. The flow chart for the complete calculation is shown in fig. 1.

Table 1: Commercially available HDPE pipe dia and their cost [Babu Jinesh et al, 2009]

S.No	Commercially available dia size(mm)	Cost per unit length (units)
1	25.40	2
2	50.80	5
3	76.20	8
4	101.60	11
5	152.40	16
6	203.20	23
7	254.00	32
8	304.80	50
9	355.60	60
10	406.40	90
11	457.20	130
12	508.00	170
13	558.80	300
14	609.60	550

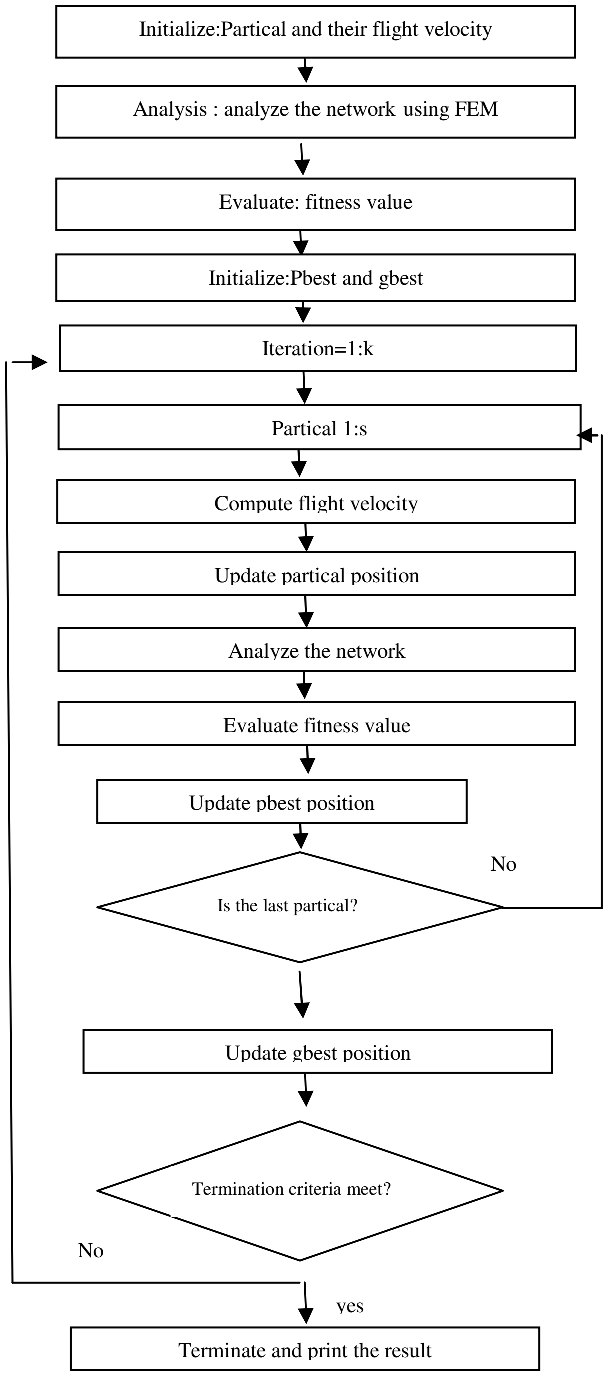

Fig.1 Flowchart of optimization using PSO

The two loop network used for validation is shown fig.2. It has 8 pipe and 7 nodes (including reservoir). Head at node 1 is to be maintained as 210 m [Babu Jinesh et al, 2009]. Commercially available diameters, used for the network are given in table 1. Elevation and demand at each junction and pipe length for each pipe is shown in fig 2. Minimum head at each junction is required to be maintained as 30 m.

As seen in fig.2 that all pipes of network are of constant length of 1000m. The finite element method is used for calculating head and velocity in pipe network, using Darcy Weishbach equation: for head loss.

$h_f = f*L*V^2/(2*D*g)$ -------(III)

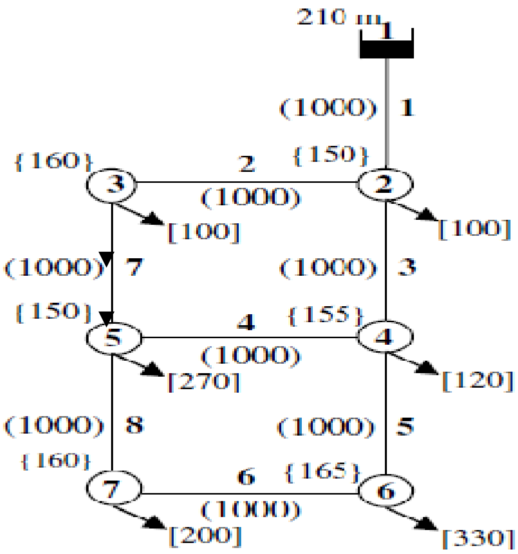

Fig.2 Two loop water distribution network [Babu Jinesh et al, 2009]

Optimization of the network for minimum cost is done for eight different variants of inertia weight function of PSO [Bansal et al, 2011].Following variants of inertia weight are used in present work:

Type	Name of Inertia Weight Function	Formulae of Inertia Weight
1	Constant Inertia Weight	ω_1=.7
2	Random inertia weight	$w_1 = .5 + \frac{rand(1)}{2}$
3	Linear decreasing inertia weight	$w_l = w_{max} - [\frac{(w_{max} - w_{min})}{maxiteration}] \times iteration$
4	Logrithmic inertia weight	$w_1 = .5 \times (1 + \frac{1}{1 + \log(iteration)})$
5.	Natural exponent inertia weight strategy e-1 PSO	$w_1 = w_{\min} + (w_{\max} - w_{\min}).e^{\left[-\left(\frac{iter}{\frac{\max iteration}{10}}\right)\right]}$
6	Natural exponent inertia weight strategy e2-pso	$w_1 = w_{\min} + (w_{\max} - w_{\min}).e^{\left[-\left(\frac{iter}{\frac{\max iteration}{4}}\right)\right]^2}$
7.	Simulated annealing inertia weight	$w_1 = w_{\min} + (w_{\max} - w_{\min}) \times \lambda \wedge (iter - 1)$ Here $\lambda = 0.95$
8.	Time varying inertia weight	$w_1 = [(w_{\max} - w_{\min}) \times \frac{(\max iteration - iter)}{\max iteration}] + w_{\min}$

4. RESULTS AND DISCUSSION

The optimization of network shown in fig 1 is done with the minimum pressure head constraint of 30 m at all juctions of network. PSO is used for optimization and coding is done in matlab environment. The result obtained after 100 iterations, for 15 trials of different swarm sizes are shown in Fig. 3:

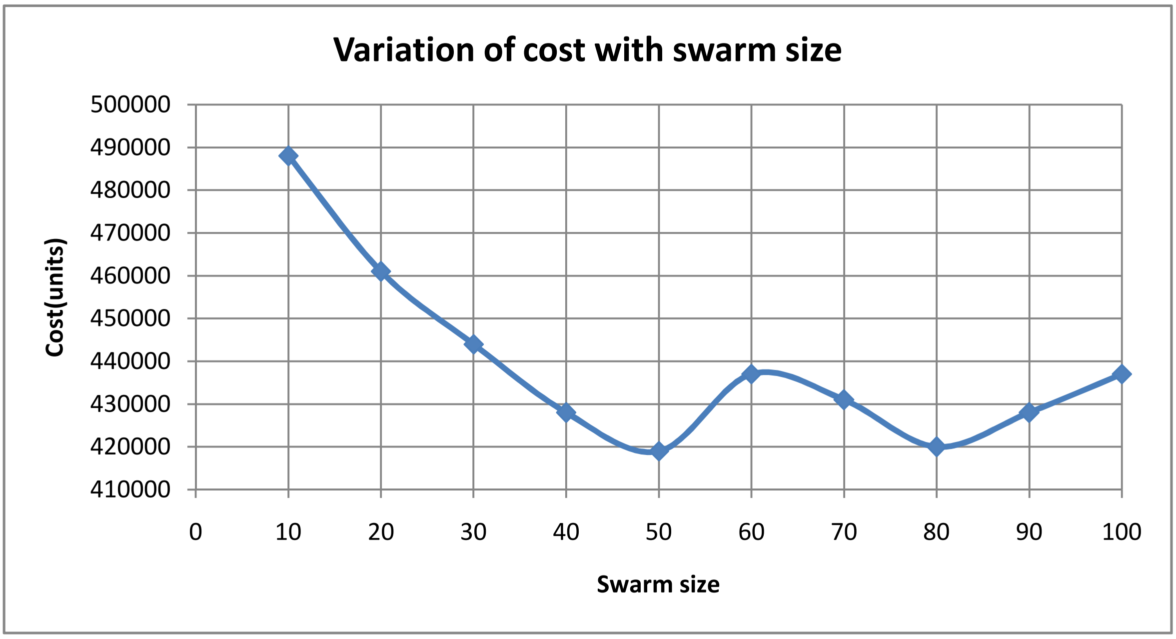

Fig.3 Variation of cost with swarm size

Table 2: Comparison of diameter and Head with the previous results of the same net work

Pipe no	Dia(present work) (m)	Dia(Jinesh et al 2014) (m)	Node no	Head(present work)(m)	Head(Jinesh et al 2014)(m)
1	0.457	0.457	1	210.00	-
2	0.254	0.254	2	53.1931	53.25
3	0.4064	0.4064	3	30.2319	30.46
4	0.1016	0.1016	4	43.3534	43.45
5	0.4064	0.4064	5	33.4958	33.81
6	0.2540	0.2540	6	30.2767	30.44
7	0.254	0.254	7	30.4233	30.55
8	0.254	0.254			

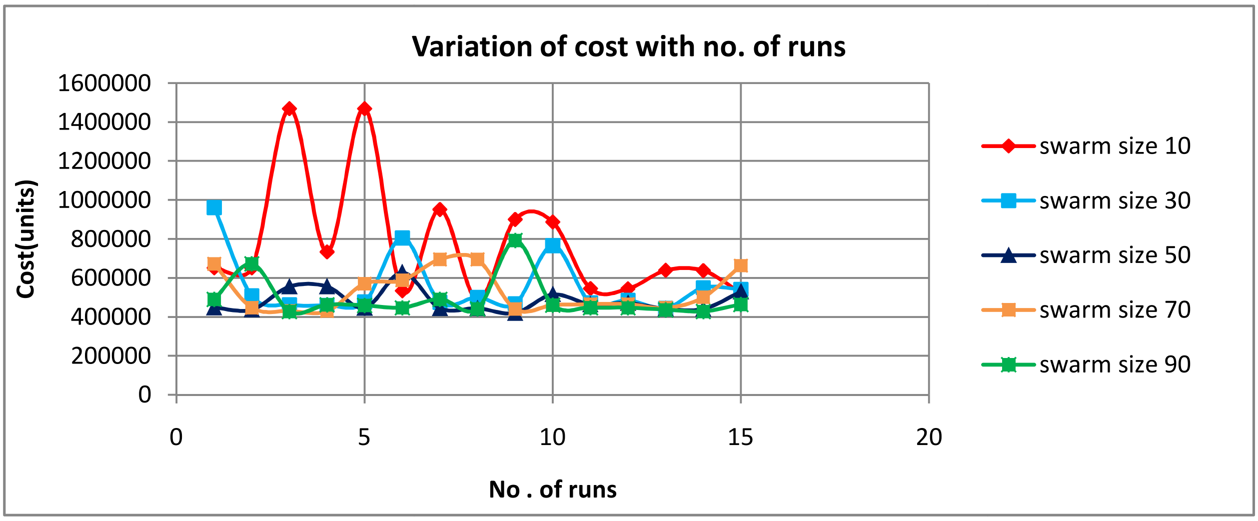

Fig.4.variation of cost with no of runs for various swarm size

It is observed from the fig.3 that cost of network is varying with swarm size and the least cost of network is obtained for swarm size of 50.The cost obtained with number of runs for each swarm size is represented graphically in fig.4, which shows that the least cost is at swarm size 50 .The pressure head at junction are closely matching with the results obtained by jinesh et al.

Further the network is optimized for 50 swarm size and 15 runs by using eight variants of weighted function. It is observed that the network cost considerably varies with type of variant (Fig.5). It is least i,e, Rs 4,19,000 for 4th type of variant which is logarithmic Inertia weight, where as it is highest in case of random inertia weight (2nd type) varient. It is because the rate of convergence is high in case of logarithmic inertia weight (Bansal et al). Minimum cost in previous work is also observed as 419000 units.

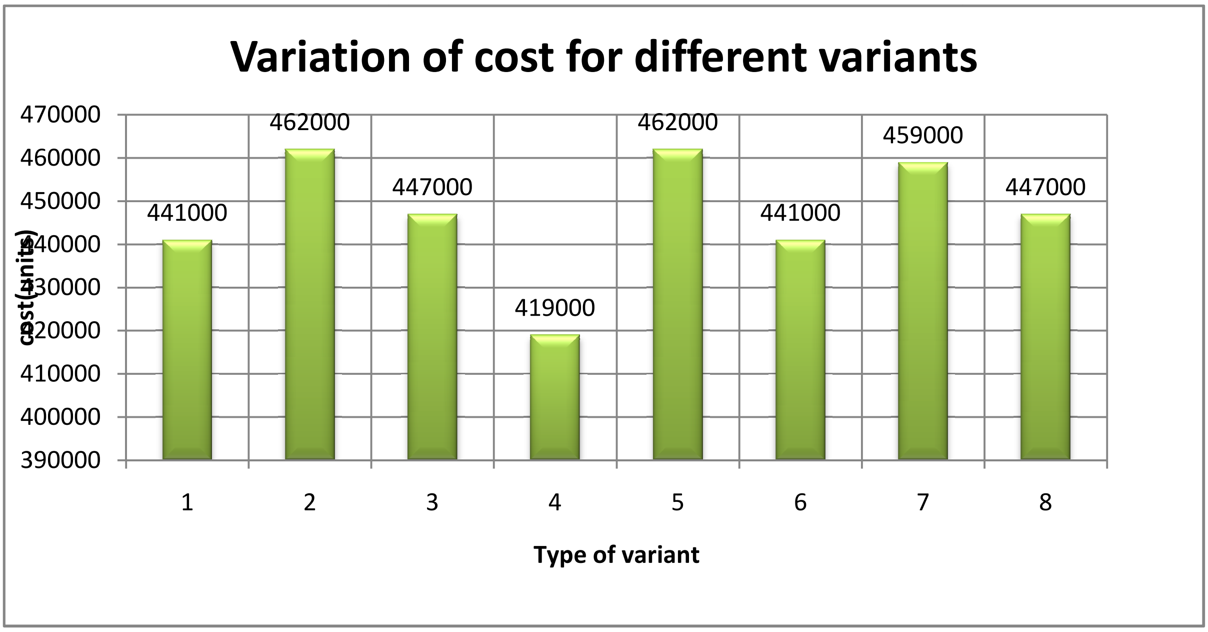

Fig 5. Variation of cost for different types of variants

Table 3: Diameter and flow for different pipe.

No of pipe	Diameter(m)	Flow(L/sec.)
1	0.457	0.311
2	0.254	0.0934
3	0.4064	0.1899
4	0.1016	0.0092
5	0.4064	0.1474
6	0.2540	0.0557
7	0.254	0.0656
8	0.254	0.0002

The optimum set of diameters (for best result i.e. 4th variant) for each pipe of two loop network is given in table 3. The pressure head at each junctions (the pressure head at junction 1 is fixed i.e, 210m) is depicited in table 4. It is seen that the lowest value of pressure heads are at type 4 inertia weight (Logrithmic Inertia weight). This is because no. of iterations and swarm size is fixed for all types of inertia weights in this analysis, but the rate of convergence is high for logrithmic inertia weight. Others may also achieve the low pressure head values at higher number of iterations.

Table 4: Values of pressure head at all junctions for different types of Inertia weights

Node No.	Pressure head for Type 1 variant	Pressure head for Type 2 variant	Pressure head for Type 3 variant	Pressure head for Type 4 variant	Pressure head for Type 5 variant	Pressure head for Type 6 variant	Pressure head for Type 7 variant	Pressure head for Type 8 variant
2	53.1931	53.1931	53.1931	53.1931	55.9806	53.1931	53.1931	53.1931
3	39.6279	37.5225	33.9689	30.2319	38.1285	39.6279	38.9799	33.9689
4	43.3403	44.5384	44.8001	43.3534	45.028	43.3403	43.4327	44.8001
5	38.3232	42.0028	41.2598	33.4958	44.972	38.3232	44.2504	41.2598
6	30.2666	30.3286	30.4528	30.2767	30.764	30.2666	30.232	30.4528
7	30.4258	30.5032	30.002	30.4233	30.6955	30.4258	30.0902	30.002

5. CONCLUSION

The present pipe network optimization concludes that the type of weighted integral plays an important role in network optimization. The logrithmic weighted integral is most suitable for fast convergence and cost minimization in case of water distribution network. However the suitable swarm size and number of iterations are also significant in PSO. It can be seen that forth variant gives best result with minimum cost of 419000 unit.

Notations

H_k - head available at each junction
H_{min} - Min head required to be available at the junction
K - total no. of junction in the network
h_f - head loss
f - friction factor
L - length of the pipe
V - velocity in the pipe
D - diameter of the pipe

REFERENCES

1. Wu Z.Y. and Simpson A.R. (2001), Competent genetic evolutionary optimization of water distribution system, Journal of computing in civil engineering, volume 15(2), pp 89-101.
2. Keedwell Edward and Thiam Khu Soon, (2004)" A hybrid genetic algorithm for the design of water distribution networks", Engineering applications of artificial intelligence, volume 18, pp 461-472.
3. Afasher M.H. and Marino M.A. (2005),"A convergent genetic algorithm for pipe network optimization", Scientia Iranica,volume 12(4),pp-392-401.
4. Mahor Amita, Prasad Vishnu, Rangnekar Saroj (2009)," Economic dispatch using particle swarm optimization: A review", Renewable and sustainable energy reviews, volume 13,pp. 2134-2141.
5. Bansal Jagdish Chand and Deep Kusum,(2009) "Optimal design of water distribution networks via partical swarm optimization", IEEE International advance computing conferece,pp-1314-1316
6. Bansal J. C,Singh P.K,Saraswat Mukesh,Verma Abhishek,Singh Jodan shimpi and Abraham Ajith,(2011)," Inertia weight strategies in partical swarm optimization", Proceedings of Third World Congress on Nature and Biologically Inspired 978-1-4577-1123-7/11,pp-640-647.
7. Babu Jinesh K.S. and Vijayalakshmi D.P(2013),"Self adaptive PSO-GA hybrid model for combinatorial water distribution network design", Journal of pipeline systems engineering and practice,volume-4(1),pp. 57-67.
8. Izquierdoa J.*, Montalvob I., Pérez-Garcíaa R., Campbella E.(2014)," Mining solution spaces for decision making in water distribution systems", Science direct,12th International conference on computing and control for the water industry,CCWI2013,volume-70,pp-864-871.
9. Manual on water supply and treatment (1991), Published by central public health and environmental engineering organization, Ministry of urban development, Third edition.
10. Shrivastava Minakshi,Khare Ruchi and Prasad Vishnu(2014),"Effect of pressure dependent demand on pipe network analysis:A case study", International Journal of Engineering Science and Technology, volume 6(1),pp 7-12.
11. A.Raja Jeya Chandra Bose, Dr.T.R.Neelakantan, Dr.P.Mariappan, "Peak Factor In The Design of water Distribution- An Analysis" International Journal of Civil Engineering & Technology (IJCIET), Volume 3, Issue 2, 2012, pp. 123 - 129, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316.
12. A.Sri Rama Chandra Murty and M. Surendra Prasad Babu, "Implementation of Particle Swarm Optimization (PSO) Algorithm on Potato Expert System" International Journal of Civil Engineering & Technology (IJCIET), Volume 4, Issue 4, 2013, pp. 82 - 90, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316.